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ABSTRACT

The purpose of this study was to investigate the relationship between the achievement of some abstract concepts in "molecular genetics" and prior knowledge, formal reasoning ability, and sex. The major findings of the study were: (1) prior knowledge had a high significant correlation with the achievement of abstract concepts; (2) the correlation between the formal reasoning and the achievement of abstract concepts was found to be relatively moderate, but significant; (3) sex was found to correlate significantly but low with the achievement of abstract concepts; (4) the variables succeeded in predicting the achievement of abstract concepts; and (5) a relatively high percentage of variability in the achievement of abstract concepts was accounted for by prior knowledge and formal reasoning. The major conclusions of this study are that the prior knowledge and formal reasoning play a major role in students' achievement of abstract concepts, and the effect of student's prior knowledge on this achievement seems to exceed that of formal reasoning. A 7-page list of references is included. (CW)

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The Relationship between Abstract Concept Achievement and Prior Knowledge, Formal Reasoning Ability, and Sex among some Egyptian Secondary School Students

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ABSTRACT

The Relationship Between Abstract Concept Achievement and Prior Knowledge, Formal Reasoning and Sex Among Some Egyptian Secondary School Students

The purpose of this study was to investigate the relationship between the achievement of some abstract concepts in "molecular genetics" as a dependent variable and a set of the following three independent variables : (1) the prior knowledge; (2) formal reasoning; and (3) sex. The data were collected using 160 third grade secondary School students drawn from one public school in the city of Idku, Egypt. The subjects were administrated three tests. The first test was used to measure students prerequisite knowledge concerning the topic of "genes and nucleic acids". The second test was used to measure the achievement of abstract concepts included in this topic. The Test of Logical Thinking was used to measure the formal reasoning. The statistical treatments used in the study were : (1) Pearson product-moment correlation coefficient; (2) multiple regression procedure; (3) stepwise method. The major findings of the study were : (1) the prior knowledge was correlated significantly high with the achievement of abstract concepts ($r = .74$, $p < .0001$); (2) the correlation between the formal reasoning and the achievement of abstract concepts was found to be relatively moderate and significant ($r = .53$, $p < .0001$); (3) sex was found to correlate significantly ($p < .05$) but low with the achievement of abstract concepts.; (4) the set of the three independent variables were succeeded in predicting the achievement of abstract concepts ($R^2 = .63$, $p < .0001$) and; (5) the stepwise method selects the prior knowledge, formal reasoning and sex in the first, second, and third steps respectively; and (6) a relatively high percentage of variability (about 60%) in the achievement of abstract concepts was accounted for by the prior knowledge and formal reasoning. The major conclusions of this study are : (1) the prior knowledge and formal reasoning play a major role in students' achievement of abstract concepts and; (2) the effect of student' prior knowledge on this achievement seems to exceed that of formal reasoning.

The Relationship between Abstract Concept Achievement and Prior Knowledge, Formal Reasoning Ability, and Sex among some Egyptian Secondary School Students

Background

Results of numerous investigations conducted during the past two decades in Western countries have shown that a large portion of high school and college students find difficulty in understanding scientific abstract concepts (e.g., Lawson & Renner, 1975; Driver & Easley, 1978; Griffiths & Grant, 1985; Marek, 1986). Surprisingly, similar investigations carried out lately in non-Western cultures, including the Arab countries, have reached the same results (e.g., Za'Rour & Gholam, 1981; Billeh & Khalili, 1982; Al-Mazore, 1982; Atiew, 1985). Science educators have shown intensive concern in such students' deficiency of understanding the abstract concepts whereas many of the concepts covered in secondary school and college science are of highly abstract entities (e.g., Renner & Grant, 1978, Shayer & Adey, 1981). Thus, searching for factors that might cause this deficiency has become an area of interest. A great bulk of research has been conducted accordingly, and most of this research has utilized two competing theoretical perspectives : Piaget's model of intellectual development (Piaget, 1964; Inhelder & Piaget, 1958) and Ausubel's model of meaningful verbal learning (Ausubel, 1963; 1968).

Piaget characterized human intellectual development in terms of four stages (Inhelder & Piaget, 1958). The first two, called sensory-motor and preoperational, are usually completed when a child is seven or eight years old. Following these are two stages of logical operations, called concrete thought and formal thought which are relevant to most of children's school years. Each of the latter stages is somewhat characterized by its own reasoning operations. The concrete thought includes a number of concrete operations (e.g., classification, seriation, and conservation) which make use of direct experience, concrete objects, and familiar actions. On the other hand, the formal thought consists of more advanced operations called "formal reasoning operations". They are based on abstraction and transendent experience (Karplus, 1977). Basic to the formal operations are : hypothetical deductive reasoning, sollogistic reasoning, combinatorial reasoning, correlational reasoning, probablistic reasoning, proportional reasoning and control of variables (Lawson, 1985).

Researchers utilizing Piaget's model tend to hypothesize that the meaningful understanding of the abstract concepts demands the development of formal thought on the part of learners. This hypothesis has been confirmed in a number of studies (e.g., Cantu & Herron, 1978; Goodstein & Howe, 1978; Billeh & Khalili, 1982; Al-Mazroe, 1982). Some correlational evidence between formal thought and achievement of abstract concepts also exists to support this hypothesis

(e.g., Lawson, Nordland & Devito, 1975; Wheeler & Kass, 1978; Zeitoun, 1981; Lawson, 1982; Atiew, 1985).

On the other hand, Ausubel and his followers (e.g., Ausubel, 1963; 1968; West & Fensham; 1974; Novak, 1977a) have looked to the question of students' acquisition of abstract concepts from a different perspective. That is the role of prior knowledge in meaningful verbal learning. Ausubel (1968) maintains that "the most important factors influencing learning is what the learner already knows. Ascertain this and teach him accordingly" (p. vi). He postulates that meaningful acquisition and retention of new knowledge is a function of the number and kinds of relevant background knowledge already possessed by the learners. For Ausubel, prior knowledge plays an organizing or subsuming role in facilitating meaningful learning. Ausubel's postulates were substantiated in some previous investigations (e.g., Novak, Ring & Tamir, 1971; West & Fensham, 1976; Mintzes,1979; Hewson & Hewson, 1983).

Rationale and Related Literature

The past decade had witnessed a controversy between the "Ausubelian" and "Piagetian" science educators regarding the relative importance of prior knowledge and formal reasoning ability in students' understanding of abstract concepts, hence in the achievement of these concepts. Joseph Novak, the most advocate of Ausubel's postulates, claims that children who lack formal thought may acquire some abstract concepts so long as they possess the relevant background

knowledge (Novak, 1977b). Piaget's followers (e.g., Lawson, 1977; Herron, 1978) attached Novak's position. They argue that students who have not attained formal operational reasoning will not be able to comprehend meaningfully abstract concepts and principles of science.

This controversy might have raised the following question : which of the two factors, the prior knowledge or the formal reasoning is the most determinant of abstract concept achievement. Recently, two investigations (Lawson, 1983, Chandran, Treagust & Tobin 1987) have been addressed partially to answer the above question. Results of the two investigations were somewhat inconsistent. Lawson (1983) found a relatively moderate correlation between the abstract concept achievement and prior knowledge ($r = .34$, $p < .001$), while, the correlation between this achievement and formal reasoning was very low ($r = 0.18$, $p < .05$). He also found that the variance amount of the achievement accounted for by the prior knowledge exceeded that of the formal reasoning. The abstract concept achievement was estimated by students' total scores in three examination items : multiple choice items, computional items, and an essay item. These items covered an undergraduate's understanding of some abstract concepts regarding evolution and natural selection. However, Chandran et al. (1987) found that the relationship between abstract concept achievement of secondary school students and their prior knowledge was somewhat low ($r = 0.23$, $p < .001$), while the relationship between the achievement and formal

reasoning ability was relatively moderate (r = .38, $p < .0001$). Also, the regression and path analysis carried out in Chandran et al.'s indicated that both the formal reasoning and prior knowledge were relatively good predictors of this achievement. And that the effect of the formal reasoning on such achievement exceeded that of the prior knowledge. The achievement was measured in this investigation by a multiple choice test, that covered some chemistry thems such as the mole concept, kinetic theory, and periodic table.

Apparently, the inconsistent results of the previous investigations have left the aforementioned question without a conclusive answer. Thus, new investigations that tackle this question seem to be warranted. Hence, this investigator feels the need for a study that keeps inquiring about the relative importance of the prior knowledge and formal reasoning on abstract concept achievement. This study could also investigate the effect of the sex variable on this achievement. Results of previous investigations were contradictory with regard to the effect of sex on such achievement (e.g., Okeke, 1979; Billeh & Khalili, 1982; Fleming & Malone, 1983; Fields, 1984). Details of sex-related difference in science achievement and its possible explanations are available elsewhere (e.g., Erickson & Erickson, 1984; Hyde & Linn, 1986).

Moreover, the present investigator feels a need to consider the major concepts of "molecular genetics" as a subject of this achievement. Previous research carried out in

Western cultures indicated that some concepts of "molecular genetics" were very difficult to learn (e.g.; Fisher, 1985; Fisher, Lipson, Hildebrand, Migual, Schoeberg& Porter, 1986). Also, some Egyptian biology teachers, surveyed by this investigator, consented that these biological concepts, taught to secondary school students, are the most difficult ones. Hence, looking for some factors that could explain this difficulty is justifiable.

Purpose

The problem addressed in this study was mainly to examine the relative contribution of the following independent variables (predictors) : prior knowledge, formal reasoning ability, and sex, collectively and seperately, to the abstract concept achievement in"molecular genetics"as a criterion variable. Specifically, this study addressed itself to the fulfillment of the following major objectives : (a) to find out the relationship between each of the indpendent variables and the criterion variable; (b) to determine the contribution of the three independent variables to the variability of the criterion variables; and (c) to select the best predictors of the criterion variable from the independent variables.

Definition of Terms

Achievement : "Knowledge attained ... in school subjects, usually designated by test scores" (Good, 1973, p. 7). In this study, achievement was measured by the subject total score on "The Achievement Test in Molecular Genetics" which

was constructed by this investigator.

Abstract Concepts (Formal Concepts) : "[Theoretical] concepts whose meaning is derived through position within a postulatory-deductive system. The term postulatory deductive system refers to the theoretical models (systems) of science. Meaning is given to these concepts not through sences but through imagination or through their logical relationship within the system" (Lawson & Renner, 1975, p. 348). An abstract concept, e.g., genetic code (codon)[1] cannot be concretely experienced. Understanding of a "codon" is derived from a set of postulates dealing with the nature of nucleotides, messenger ribonucleic acid (mRNA), amino acids and protein synthesis. In this study, the abstract concepts refered to the major theoretical (formal) concepts regarding the unit of "genes and nuleic acids" taught to Egyptian secondary school students, third grade.

Formal Reasoning Ability : Capability of dealing with formal reasoning operations, e.g., proportional reasoning, control of variables, correlational reasoning, probabilistic reasoning and combinatorial reasoning (Lawson, 1985). In this study the formal reasoning ability was measured by the subject total score on "The Test of Logical Thinking (TOLT)" as develped by Tobin & Capie (1981).

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(1) Codon : A Sequence of three nucleotides on a mRNA molecule that directs the placement of a particular amino acid during the process of protein synthesis.

Prior Knowledge : background knowledge already acquired in a subject matter area(s) which is relevant to subsequent learning of new knowledge in this (these) area(s). In this study the prior knowledge was assessed by the subject total score on "The Prior knowledge Test in Genes" which was constructed by this investigator.

Limitations

1. The sample was confined to third-grade (twelfth grade) students (scientific section) enrolled at Idku Co-education Secondary School, Boheriah Gevernorate, Egypt, during the school year 1986-1987. This puplic school is located in a rural area.
2. The assessment of abstract concept achievement was limited to the major concepts concerning the unit of "genes & nuleic acides". The unit is part of the national biology curriculum set for secondary school students, third grade. This assessment was carried out on the first three levels of Bloom's taxonomy of educational objectives : the cognitive domain (Bloom, Hastings & Madaus, 1971). That is to say, knowledge, comprehension and application. Subjects were taught the unit of "genes & nucleic acids" by their classroom teacher via lecture method.
3. The prior knowledge was limited to the prerequiste knowledge needed for understanding the unit of "genes & nucleic acids".
4. The Test of Logical Thinking is a paper and pencil

instrument. Evidence indicates that paper and pencil instruments seem to be less valid than Piaget's clinical interview (Inhelder & Piaget, 1958) with regard to the assessment of reasoning operations (see, e.g., Ahlawat & Billeh, 1987).

5. The design of this study is limited to the correlational analysis design. This design cannot usually establish a causal relationship, but, it can help possibly in providing some hints of causality (Punch, 1971).
6. This study was completed in about four weeks; one week for instrument administration and three weeks for teaching the unit of "genes and nucleic acids".

Methodology

The Sample

The sample of this study consisted of 160 secondary school students, third-grade (85 males and 75 females). They represent the total number of students in four intact classes. These classes were drawn randomly from 8 classes in a coeducation school in the city of Idku, Egypt. The age of the students ranged from 17.3 to 18.7 with an average of 17.6 years (SD = 1.1).

The Instruments

Three paper and pencil instuments were used for data collection : (a) The Achievement Test in Molecular Genetics (ATMG); (b) Test of Prior Knowledge in Genes (TPKG); (c) The Test of Logical Thinking. The first two instruments were constructed by this investigator. A brief description of

the above instruments follows :

The Achievement Test in Molecular Genetics (ATMG) : This test was constructed to measure students' achievement of six major concepts of molecular genetics. These concepts include: deoxyribonucleic acid (DNA), DNA duplication, ribonucleic acid (RNA), RNA transcription, genetic code and protein synthesis. These concepts were determined through the content analysis of the unit titled : "genes and nucleic acids", as found in the biology set book of the Egyptian secondary school, third grade. This analysis was carried out independently by this investigator, together with a science educator and college geneticist at agreement amounted to 90%. A preliminary pool of 60 multiple choice items that covered the above six concepts were subject to revision procedures as explained fully by Bloom et al. (1971, pp. 73-82). The final from consited of 43 items which takes about forty-five minutes to administer, and has a score range of 0-43. Examples of test items fellow :

(1) The number of letters which constitutes the genetic langauge" or "alphabet" is :

(a) 3.

(b) 28.

(c) 20.

(d) 64.

(e) 4.

(2) Which of the following controls the sequence of amino acids in a protein synthesized in cells ?

a. the sequence of nitrogenous bases carried by massenger RNA.

b. the sequence of ribosomes in cell cytoplasm.

c. the sequence of amino acid numbers.

d. the way ribosomes read the genetic code carried by transfer RNA.

e. the sequence of peptide bonds that link the amino acids in protein molecules.

In terms of validity, a coefficient of content validity was computed for the"ATMG"using the Kendall coefficient of concordance (Ferguson, 1971). A validation coefficient of 0.82 ($p < 0.05$) was calculated for four experts (two college geneticists, and two science educators) who rated the test on the criteria of (1) representativeness of the items from the total pool of possible items for the content covered, (2) readability and understanding of items. The reliability of this test, estimated by Kuder-Richardson Formula 20 (Bloom et al., 1971), was found to be 0.75 ($p < 0.05$).

The Prior Knowledge Test in Genes (PKTG). This instrument was designed to assess students' prerequisite knowledge about the aforementioned six abstract concepts as included in the unit of "genes & nuleic acids". This knowledge concentrates on the following themes : structure of nuleotides; characteristics of amino acids, protein and enzymes; chemical bonds; and cell structure and division. These concepts were detemined by this investigator with the help of two college geneticists. That knowledge was thought to be essential for

learning those abstract concepts. The final form of the instrument consisted of 31-four alternative multiple choice items. They were selected from an original pool of 53 questions. This selection was based on the results of a number of revising procedures as proposed by Bloom et al. (1971, pp. 73-82). The raw score range of the "PKTG" was 0-31. It required roughly 35 minutes for administration.Two items of the test appear below :

(1) Which of the following characteristics is not of enzymes ?

a. act as catalysts that increase the rate of biochemical reactions.

b. are very specific, i.e., each catalyzes only one or very few reactions.

c. belong to the Vitamin class.

e. function with a relatively low concentration.

(2) Which of the following characteristics is not of chromosomes ?

a. have the ability to duplicate it self.

b. carry genes.

c. their number is constant in the somatic cells for each species.

d. Each carries one genetic factor.

The instrument content validity was estimated by the same method used with the "ATMG". A validation coeficient of 0.79 ($p < .05$) was obtained. The internal consistency reliability cofficient of the"PKTG"estimated by K-R 20 formula, was 0.66 ($p < .05$).

The Test of Logical Thinking (TOLT) : This test was developed by Tobin and Capie (1981) to measure the formal reasoning ability. The TOLT is a paper and pencil test consisting of 10 items; each two for the categories of proportional reasoing, controlling variables, probabilistic reasoning, correlational reasoning and combinatorial reasoning. In the test a situation is presented, five possible solutions are described, and the subject selects from the five reasons the one that he believes to support the solutions he has chosen. To be scored correct both the answer and the reason must be correct. For combinatorial reasoning the subjects arrange symbols in as many combinations as possible. Tobin and Capie reported a Cronbach alpha reliability of 0.85 and a criterion related validity of .76 (0.82 when corrected for attenuation). The English version of the test was translated into Arabic by this investigator and a colleague[1] from the Department of English Methodology, University of Tanta, Egypt. A pilot testing was undertaken to determine cross-cultural utility of the test and to determine similarities and testing time. As a result of this pilot study, a few changes were made to the TOLT, resulting in a slightly modified Arabic version. The calculated reliability, using Cronbach's alfa formula (Cronbach, 1951) for this Arabic version was (0.76, $p < 0.05$). This version required about 30 minutes for adminstration.

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(1) Dr. Mohamed R. Issa.

The possible range of the raw scores in the test was 0-10.

Administration of the Instruments :

Both "The Test of Logical Thinking" and "The Prior Knowledge Test in Genes" were adminstered before teaching the unit of "gene & nucleic acids" to the subjects. The administration of "The Achievement Test in Molecular Genetics" took place upon the end of this teaching, about three weeks later. Each of the above instruments was conducted in a seperate session held on a different day.

Statistical Procedures :

Three statistical procedures were used to analyze the data : A product moment correlation analysis, a multiple regression analysis (Kerlinger & Pedhazur, 1973) and stepwise analysis (Draper & Smith, 1981). Product moment correlations were calculated by SAS-CORR computer program as a measure of the strength and direction of the relationship between the criterion variable and the three independent variables (predictors). The amount of variance in the dependent variable accounted for by a linear combination of the three predictor variables was determined by multiple regression analysis. This regression analysis was executed by SAS-REG computer program. The stepwise analysis was performed by SAS-STEPWISE computer program to select the best predictors of the criterion variable from the set of independent variables. The selected variables were included in the stepwise prediction equation. The three computer programs, SAS-CORR, SAS-REG, and SAS-STEPWISE were avaiable at King Saud

Computer Center, Riydah, Saudi Arabia. When sex variable was included in any of the three statistical analysis, males were reported as (0) and females were reported as (1).

Results

The mean and standard deviation for the criterion variable as well as the three independent variables are reported in table I.

Table II presents the Pearson product-moment correlation matrix of the study variables. This correlation matrix indicated that the achievement of abstract concepts was statistically significantly related to the prior knowledge ($r = 0.74, p < 0.0001$), the formal reasoning ability ($r = 0.53$, $p < 0.0001$), and sex ($r = 0.16$, $p < 0.05$). The difference between the correlation coeficient regarding the prior knowledge and this achievement and that of the formal reasoning and the same achievement was found to be signficant ($p < 0.001$). Details regrading the computation of this difference between the two correlations could be found in a number of statistical books (e.g., Ferguson, 1971).

The results of the multiple regression analysis are presented in table III. This table represents the summary table of analysis of variance (F test) related to the squard

Table 1

Descriptive Statistics of the Study Variables

Varible Name	Variable type	Variable Mean	Variable S.D.	Maximum Score Possible
Abstract Concept Achievement	Criterion	23.50	5.97	43
Prior Knowledge	Independent (1)	14.50	3.75	31
Formal Reasoning Ability	Independent (2)	2.30	1.61	10
Sex	Independent (3)	0.53	0.50	1

(19)

Table II

Pearson Product Moment Correlation Matrix

	Abstract Concept Achievement	Prior Knowledge	Formal Reasoning Ability	Sex
Abstract Concept Achievement	1.0	0.74*	0.53*	0.16**
Prior Knowledge		1.0	0.43*	0.07
Formal Reasoning Ability			1.0	- 0.19**
Sex				1.0

* $p < 0.0001$

** $p < 0.05$

multiple correlation coefficient (R^2)[1] between the criterion variable and the combined three independent variables. This R-square was found to be 0.63 ($p < 0.0001$). This could mean that the combined variables account for 63% of the variance regarding the abstract concept achievement.

Table IV shows the summary of stepwise results. This procedure selected all the independent variables to be included in the prediction equation of the achievement of abstract concepts. The prior knowledge (PK) was selected in the first step. Formal reasoning ability (FRA) and sex entered the equation in the second and third steps respectively. The R-squares associated with the entrance of the prior knowledge alone and of both the prior knowledge and formal reasoning ability into this equation were 0.54, 0.60 respectively. Adding sex to PK and FRA resulted in very limited increase in the amount of the overal R-square i.e, 0.63. Then, this amount of increase was only 0.03.

Table IV shows also that raw score formula of the prediction equcation was :y=0.37+0.94(PK)+1.15(FRA)+2.17(SEX).

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(1) R-square is usually used in examining the amount of variance regarding the criterion variable which is accounted for by the predictor variable , while F ratio is used in determining if the predictor variables are significant predictors of the criterion variable.

Table III

Analysis of Variance (F Test) of R-Square (R^2) Related to the Prediction of Abstract Concept Achievement.

Source	df	Sum of Sauares	Mean Squares	F Value	P>F	R. Square
Model	3	3566.64	1188.88	87.87	0.0001	0.63
Error	156	2110.18	13.53			
Corrected Total	159					

(22)

Table IV

Summary Table of Stepwise Analysis for

The Prediction of Abstract Concept Achivement

Step Number	Variable Enter	R. Square	F	P > F
Step I	Prior Knowledge (PK)	0.54	186.23	0.0001
Step 2	Formal Reasoning Ability (FRA)	0.60	116.30	0.0001
Step 3	Sex	0.63	87.87	0.0001
	B Value	STD Error	F	P > F
Intercept	8.37			
PK	0.94	0.09	116.36	0.0001
FRA	1.15	0.21	31.15	0.0001
SEX	2.17	0.60	13.09	0.0004

Discussion

The results of this study are generally supportive of Ausubel's model and perhaps the Piaget's model as well. The highly significant relationship between the prior knowledge and the achievement of the abstract concepts (r = 0.73) came in line with the aforementioned Ausubel's postulate concerning the role of prior Knowledge in concept learning. This high relationship substantiated some previous investigations which were addressed to verify this postulate (see, e.g, Novak et al., 1971; Mintzes, 1979). On the other hand, a relatively moderate relationship between the formal reasoning ability and the achievement of abstract concepts (r = 0.53) could support the Piagetian perspective regarding the facilitating effect of formal reasoning operations on abstract concept achievement (Karplus, 1977; Lawson & Karplus 1977). These results might also support some previous investigations on the relationship between the students' developmental stages and science achievement (e.g., Lawson, et al., 1975; Zeitoun; 1981; Lawson, 1982; Atiew, 1985; Chandran et al. 1987).

Also, the results of the stepwise analysis (table IV) might provide more support to each of the models of Ausubel and Piaget. Mainly, these results could indicate that both the prior knowledge and the formal reasoning ability are considerably good predictors of abstract concept achievement. Both variables account for 60% of this achievement variance.

The stepwise results appeared to be consistent with the comparable findings of chandran et al. (1987).

Integrating the findings of the product-moment correlation analysis (table I) with that of the stepwise analysis (table IV) could possibly indicate that the contribution of the prior knowledge to the achievement of the abstract concepts seemed to exceed that of the formal reasoning ability. The relatioship between the prior knowledge and the achievement was significantly higher than that of formal reasoning and such achievement. In addition, the R-square associated with the enterance of the prior knowledge to the prediction equation was 0.54, while that of the formal reasoning was 0.06. This case of superiority concerning the relative contribution of the prior knowledge over the formal reasoning ability to students' achievement of abstract concepts could be expected. Novak et al. (1971) stated that the prior knowledge is the best predictor of science achievement. And, it could account for a major portion (up to 50%) of variance regarding this achievement. Also, Lawson (1983) expected that if students are supposed to learn discipline specific facts and concepts, then the best predictor of their ability to do so should be the number of discipline specific facts or concepts the students have already acquired. Lawson's expectation was confirmed by him and by the present investigation.

A word of caution is that the relative contribution of the formal reasoning ability estimated by the stepwise

analysis to the abstract concept achievement could be less than the actual one. Because of the considerable correlation between the prior knowledge and formal reasoning ability ($\underline{r}$ = 0.43, table II), the relative contribution of the latter to this achievement might be confounded by the contribution of the first variable selected earlier in the first step of the analysis. (See, e.g., Kerlinger & Pedhazur, 1973, for indepth discussion about this confounding effect).

As for the sex variable, results of the product moment correlation and the stepwise analysis tabel II and IV indicated that it has very limted role in predicting the achievement of abstract concepts. The correlation between this variable and the achievement was very low ($\underline{r}$ = 0.16, $\underline{p} < 0.05$). The variable R-square associated with its enterance to the prediction equation was = 0.03. The limited role of sex on such achievement appears to be consistent with the findings reported by Okeke (1979) and Fleming & Malone (1983), among others.

It is noteworthy that this study might achieve a considerable success over some previous investigations regarding the prediction of abstract concept achievement. Finding of the multiple regression analysis (table III) showed that the linear combination of the three independent variables accounted for a relatively hight significant proportion, i.e. 63% of the achievement variance. Conversely, the pertcentage of the achievement variance accounted for by the independent variables used in the study of Lawson, (1983), and Chandran

et al. (1987) were found to be 31.8%, 19% respectively.

Implications'

The findings of the present study might indicate that the difficulty found by both sexes with abstract concepts, could somewhat be due to their lack of prior knowledge and formal reasoning operations. There are two main implications of these findings. First, teachers need to examine students' prior knowledge before new abstract concepts are introduced. Some or all of this knowledge perhaps demands a sort of remedial instruction. The diagnostic prescriptive teaching strategies should be considered in this respect (see, e.g., Idar & Ganiel, 1985). The second implication of this study is concerned with the observed deficiency in formal operations among secondary school students (see., e.g., Chiappetta, 1976; Lawson, 1985). Teachers are required to utilize the concrete methods which could make the abstract concepts more palpable for students lacking these operations. Mostly, these methods make use of concrete materials, e.g., models, pictures, illustrations and diagrams to cross-fertilize the concrete conceptions with the abstract ones. A considerable evidence exists to indicate that these methods could, to some extent, enhance the achievement of some abstract concepts among students lacking the formal operations (e.g., Cantue & Herron, 1978; Howe & Durr, 1982; Johnson & Barufauldi, 1984; Zeitoun, 1984). It is noteworthy that the use of the concrete methods is only one alternative to deal with students' deficiency in formal reasoning operations. Another alternative is to

prepare training programs or workshops that develop these operations on the part of students (e.g., Collea & Nummedal, 1979 , Karplus, 1977). Some evidence exists to support the possibility of such training programs to accelerate the development of formal operations (DeCarcer, Gabel & Staver, (1978 ; Lawson, 1985).

It would seem wise at this point to suggest that teachers as well as curriculum developers should not look to students' achievement of abstract concepts from any particular model be it Piagetian or Ausubelian. Rather, they should benefit from both models as well as others. Perhaps, no teaching strategy of abstract concepts is available today that is based on the principles of different psychological models. Thus, the development of this strategy is warranted (Fields, 1984).

Conclusions

On the basis of the findings, and within the limitation of this study, the following conclusions are drawn : (a) both the prior knowledge and formal reasoning ability play a considerable role in abstract concept achievement (b) the contribution of the prior knowledge to the achievement seems to exceed that of the formal reasoning ability; and (c) the sex variable appears to have a very limited role in such achievement.

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